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EFFECTS OF GRAZING ON WATER QUALITY AS ASSESSED BY AQUATIC MACROINVERTEBRATES

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EFFECTS OF GRAZING ON WATER QUALITY AS ASSESSED BY AQUATIC MACROINVERTEBRATES

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In 1976 the U.S. Forest Service awarded a grant in the amount of $5000 to Dr. James V. Ward, Department of Zoology and Entomology, Colorado State University, to implement a study in the Manitou Experimental Forest on the effects of grazing as assessed by aquatic macroinvertebrates. This report presents the findings of that study.

ABSTRACT

Macroinvertebrate density, biomass, diversity and community composition were determined monthly from June 1977 to May 1978 for three sites variously affected by grazing on Trout Creek, Manitou Experimental Forest. Density values were similar at an upstream site in an ungrazed area (control site) and at two sites located in a grazed area. Biomass values were similar at the control site and the middle site while the farthest downstream site was considerably reduced as a result of having smaller-sized taxa present. Diversity decreased in a downstream manner and may reflect a slight degree of stress. Macroinvertebrate community composition was similar at all sites. Macroinvertebrate taxa intolerant of organic pollution were collected at each site in significant numbers indicating clean water conditions. Algal samples taken at the control and downstream sites also indicate clean water conditions. Fine sediment accumulation in the substrate at the grazed sites compared to the control site may reflect increased sediment as a result of grazing activities. Anchor ice formation and the lack of any riparian canopy made interpretation of the results difficult but the data indicate that low density grazing activities did not significantly affect water quality.

INTRODUCTION

Overgrazing by livestock has long been associated with environmental degradation, especially in the semi-arid West (Chapman, 1933). It has been shown to have a negative impact on stream fisheries (Gunderson, 1968) and other potential impacts have recently been proposed (Platts and Meehan, in press). Cattle grazing potentially poses three principal impacts on water quality in streams: (1) Loss of riparian vegetation, (2) input of nutrients, and (3) increased sedimentation due to collapsing of streambanks. The loss of riparian vegetation has been shown to produce significant increases in stream temperature (Ringler and Hall, 1975). Much of the stream biota has evolved in cold streams and thus may be very sensitive to temperature increases (Hynes, 1970). Modification of the natural stream temperature regime may lead to a considerable change in the composition of the stream biota (Ward, 1974). Furthermore, loss of riparian vegetation removes from the stream ecosystem the principal energy source in the form of fallen leaves (Fisher and Likens, 1972). Current theory holds that for most small streams this input of leaf material is responsible for the maintenance of stream ecosystem structure and function (Cummins, 1974). Nutrient loading from livestock waste has been shown to be an important factor in the pollution of some aquatic systems (Toetz, 1971). The high biochemical oxygen demand (BOD) created from such waste products may cause serious oxygen depletion. This is especially deleterious with regard to stream organisms which generally have high dissolved oxygen requirements (Hynes, 1970). Temperature increases would further compound this problem as higher temperatures reduce the saturation level of dissolved oxygen in the water.

Collapse of streambanks by grazing cattle often destroys undercut banks which are preferred fish habitat and provides a source for increased sedimentation. An increase in suspended solids has been shown to have several harmful effects on stream biota, especially the eggs and immature stages which are especially susceptible to smothering (Cordone and Kelly, 1961). As a result of the potential impacts, it has been concluded that livestock overgrazing presents the greatest threat to the integrity of headwater stream habitat quality in the West (Behnke and Zarn, 1976).

The composition of the macroinvertebrate community reflects past as well as present conditions thus making them useful as indicators of water quality (Goodnight, 1973). Stream macroinvertebrates have been used to assess water quality in a variety of studies dealing with different pollutants (e.g. Gaufin, 1956; Wilhm, 1966). Propst (1978) used aquatic insects in an effort to assess effects of grazing on montane streams in New Mexico. Using a limited sampling program dealing with eleven different streams, he was unable to support the value of aquatic insects as assessors of cattle grazing impacts. In the present study a single stream was intensively sampled for one year in order to assess the effects of grazing on water quality as indicated by aquatic macroinvertebrates.

DESCRIPTION OF STUDY AREA

The study was conducted on Trout Creek, a tributary of the South Platte River and the major stream draining the Manitou Experimental Forest (Fig. 1). In the study area the stream passes through coarse-textured alluvium derived from disintegrated Pikes Peak granite.

Site Gr-1 served as the control site and was located upstream from the grazed area at an elevation of 2235m. Samples were taken immediately downstream from a Parshall flume in a riffle area composed mainly of rubble and gravel. Some silt was present as well as rooted aquatic macrophytes (Veronica sp.). Riparian vegetation consisted mainly of grasses and some willows (Salix spp.). Stream width was approximately 3m.

Site Gr-2 was located approximately 350m downstream from Gr-1 and within the grazed area. This site seemed to serve as an access point for the cattle to reach the stream as the streambanks were gently sloped and there was a great deal of physical evidence that the cattle frequented the area (fecal material, hoofprints, etc.). Substrate consisted mainly of rubble installed by the Forest Service personnel prior to the first sampling date and gravel. Riparian vegetation was similar to that at Gr-1 and some Veronica was present. Stream width was 3 to 5 m.

Site Gr-3 was located approximately 1200m downstream from Gr-1, immediately below the grazed area. Rubble was installed at this site prior to sampling and considerable silting of the substrate occurred in March and April of 1978. This site was also severly affected by anchor ice during the winter. Riparian vegetation consisted mainly of willows. No rooted aquatic plants were evident at this site.

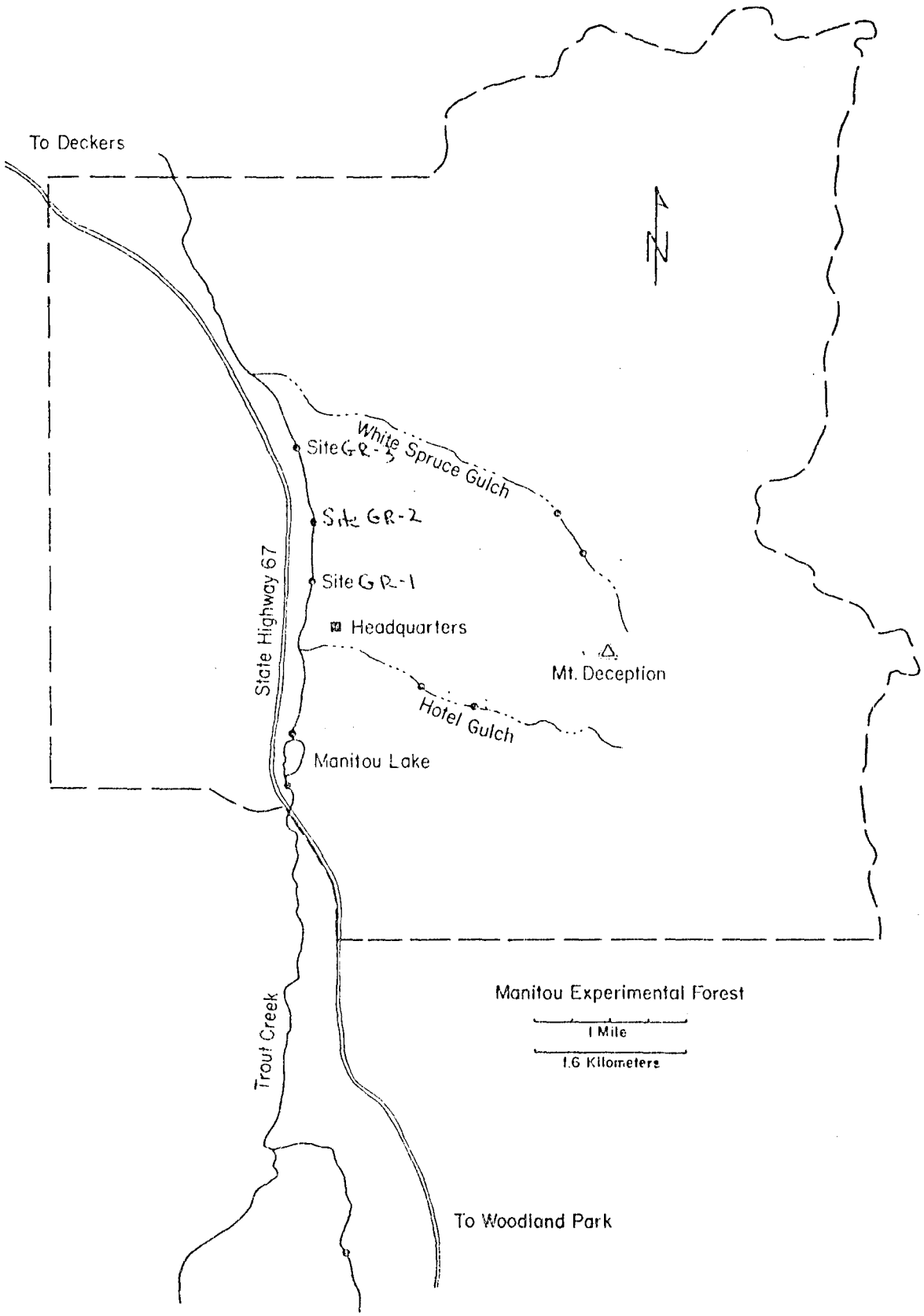


Figure 1.—Location of study sites.

METHODS

Macroinvertebrates were sampled monthly from June 1977 through May 1978 at each site. Five replicate bottom samples were collected at each site with a Surber sampler equipped with 250 μm mesh. All samples were preserved in 5% formalin. In the laboratory the organisms were separated from the detritus and placed in 80% ethyl alcohol for identification and enumeration. Biomass of the invertebrates was determined by volumetric displacement assuming a specific gravity of 1.0. Shannon-Weaver diversity was calculated from the formula:

$$\bar{d} = 3.3219/N \; (N \log_{10} N - \sum n_i \log_{10} n_i)$$ where:

3.3219=conversion factor to base 2 logarithms

N=total number of individuals

n_i=total number of individuals of i^{th} taxa.

The equitability component (e) of species diversity was calculated from the formula:

$e = s'/s$ where:

s=number of taxa

s'=table value from Lloyd and Ghelardi (1964).

Periphyton was collected monthly at Gr-1 and Gr-3 by scraping 6 glass microscope slides attached to a brick at each site. Several times at Gr-3 the brick was covered with silt and could not be located. If this occurred, a sample of approximately the same area was scraped from the rubble substrate. All periphyton samples were preserved in 5% formalin and the taxa present were identified.

Substrate samples were collected at each site in August 1977 and again in March 1978. A 15 cm diameter core was pushed into the substrate and the enclosed material was removed and placed into containers. The substrate material was dried and then separated into particle size

categories with a series of sieves. The material in each size category was weighed and its percentage of the total sample was determined.

RESULTS

A total of 40,360 organisms were collected, sorted and identified in this study. At Gr-1 48 taxa of macroinvertebrates were collected, 47 were collected at Gr-2, and 49 were collected at Gr-3 (Table 1). The same taxa (Baetis, Tricorythodes, Alloperla,Cheumatopsyche, Simulium arcticum, Orthocladius) were generally the most abundant at each site (Table 1). Mean densities were similar for the three sites (2158 organisms/m^2 at Gr-1, 2166 organisms/m^2 at Gr-2, and 1710 organisms/m^2 at Gr-3). The difference in mean density between the control site Gr-1 and the grazed site Gr-3 is not significant due to the large within site variation observed during the sampling period (Table 2). Density at Gr-1 ranged from 319 organisms/m^2 to 5451 organisms/m^2 while at Gr-3 density ranged from 233 organisms/m^2 to 6657 organisms/m^2 (Table 2). The low densities observed at Gr-3 in December and January are the result of anchor ice formation which may seriously affect the macroinvertebrate fauna of streams (Hynes, 1970). Total densities of macroinvertebrates for the three sites do not indicate any impact on water quality due to grazing.

Mean biomass values of macroinvertebrate major groups are shown in Table 3. Total biomass was nearly equal at Gr-1 and Gr-2 while it was substantially less at Gr-3. This is a reflection of the reduced numbers of large Tipula collected at this site compared to the upstream sites (Table 1). Biomass values, like density, varied widely throughout the study period (Table 4). Again there is no evidence of an impact due to grazing.

One technique used with macroinvertebrates to assess water quality is the indicator organism concept. In this technique individual taxa are classified as to their intolerance or tolerance to organic pollution.

Table 1. Mean macroinvertebrate density (no./m^2)[a] June 1977 to May 1978.

Taxon	Gr-1	Gr-2	Gr-3
Ephemeroptera			
Baetis sp.	705	934	636
Paraleptophlebia sp.	52	46	16
Tricorythodes sp.	145	57	167
Ameletus sparsatus	1	+	1
Ephemerella inermis	1	1	1
Ephemerella micherneri	9	8	3
Rhithrogena sp.	35	58	31
Epeorus longimanus	+	0	0
Cinygmula sp.	+	0	0
Plecoptera			
Alloperla sp.	94	101	66
Skwala parallela	19	12	8
Isoperla sp.	3	2	2
Capnia sp.	3	10	1
Nemoura sp.	1	1	1
Zapada cinctipes	+	1	1
Taenionema sp.	0	6	1
Pteronarcella badia	0	0	+
Coleoptera			
Optioservus sp.	10	13	10
Agabus sp.	1	+	+
Helichus sp.	0	+	+
Haliplus sp.	0	0	+
Trichoptera			
Brachycentrus sp.	14	14	2
Cheumatopsyche sp.	179	84	59
Hydropsyche sp.	13	2	4
Hydroptila sp.	4	4	0
Glossosoma sp.	25	26	32
Agapetus sp.	0	+	0
Limnephilus sp.	1	+	0
Oecetis sp.	0	+	0
Diptera			
Eriopterini	0	0	4
Tipula sp.	10	22	9
Hexatoma sp.	7	26	7
Simulium arcticum	321	277	467
Atherix pachypus	54	11	16
Pericoma sp.	1	0	+
Palpomyia sp.	1	8	2
Empididae	0	0	+
Chironomidae pupae	14	11	6
Ablabesmyia sp.	21	20	7
Cricotopus sp.	42	45	29
Diamesa sp.	23	14	+
Eukiefferiella sp.	81	74	24

Table 1. (continued)

Taxon	Gr-1	Gr-2	Gr-3
Micropsectra sp.	5	5	9
Orthocladius sp.	146	159	47
Phaenopsectra sp.	1	0	0
Potthastia sp.	2	14	1
Psectrocladius sp.	1	1	1
Rheotanytarsus sp.	37	41	11
Thienemanniella sp.	68	52	20
Tribelos sp.	3	3	+
Odonata			
Ophiogomphus severus	2	3	2
Hydracarina			
Lebertia sp.	+	+	+
Sperchon sp.	0	+	+
Amphipoda			
Hyallela azteca	1	0	+
Gastropoda			
Physa sp.	1	+	0
Helisoma sp.	+	0	0
Oligochaeta			
Eiseniella tetraedra	1	+	1
Limnodrilus sp.	0	0	5
TOTAL	2158	2166	1710

[a] + Denotes less than $1/m^2$

Table 2. Macroinvertebrate density (no./m^2) for each sampling date.

Date	Gr-1	Gr-2	Gr-3
June 6	331	2430	233
July 6	5451	3342	6657
August 8	4178	1431	2645
September 10	1602	2675	1321
October 22	2427	2070	2119
November 24	319	1515	1511
December 31	2344	2636	486
January 27	2657	2341	408
February 24	2049	1590	1436
March 24	931	701	235
April 28	2156	2971	1786
May 29	1596	2386	1741

Table 3. Mean biomass of macroinvertebrates (g/m^2 wet weight) June 1977 to May 1978.[a]

Taxon	Gr-1	Gr-2	Gr-3
Ephemeroptera	1.8	2.3	1.8
Plecoptera	1.6	0.7	0.6
Trichoptera	2.7	1.4	1.0
Diptera	5.3	7.8	2.7
Odonata	0.3	0.5	0.3
Coleoptera	+	+	+
Oligochaeta	+	+	+
TOTAL	11.7	12.7	6.4

[a] + Denotes less than 0.1 g/m^2

Table 4. Macroinvertebrate biomass (g/m^2) for each sampling date.

Date	Gr-1	Gr-2	Gr-3
June 6	3.8	8.3	4.4
July 6	10.2	16.3	12.9
August 8	10.7	4.5	4.1
September 10	3.0	4.2	3.2
October 22	11.6	16.1	7.4
November 24	2.8	10.0	10.6
December 31	13.1	13.5	3.2
January 27	16.8	11.7	1.1
February 24	20.7	14.0	19.1
March 24	19.2	13.0	1.0
April 28	19.1	24.7	4.0
May 29	10.6	16.2	7.3

Taxa present at the control site are compared to those present at the grazed sites. Organisms are classified as being either: (1) tolerant; those organisms frequently associated with gross organic pollution and able to produce large populations under nearly anerobic conditions, (2) facultative; those organisms having a wide range of tolerance and frequently found associated with moderate levels of pollution, and (3) intolerant; those organisms which are not found associated even with moderate levels of organic pollution and which require high levels of dissolved oxygen. It must be emphasized that the presence of a tolerant form does not necessarily indicate the presence of pollution. Only when intolerant forms are found is it possible to derive conclusions concerning water quality, namely that the clean water condition is present. Taxa collected in the present study were classifed as to their tolerance of pollution through the use of information contained in Weber (1973). Using this as a basis, the only tolerant taxa collected was Limnodrilus sp., which was collected only at Gr-3. Several facultative forms were collected including Rheotanytarsus, Empididae, Cheumatopsyche, and Oecetis. However by far the great majority of the taxa collected were intolerant forms. These are especially typified by the stoneflies. As stoneflies were collected at the control site and the grazed sites, it must be concluded that based upon indicator organisms no effects due to grazing were evident. However several shortcomings are associated with the indicator organism technique (Weber, 1973). Since evalutions are based only upon the presence or absence of organisms, a single individual specimen carries as much weight in the analysis as a large population. Furthermore the presence or absence of a particular taxon may be more dependent on the natural environmental conditions present rather than the degree of pollution. Also there is a

lack of quantification making comparisons difficult. To make the results more quantifiable, Beck (1955) devised the Biotic Index. He divided the macroinvertebrates into two categories:

Class I. Those intolerant of pollution.

Class II. Those which can tolerate moderate organic pollution.

The Biotic Index is calculated from the equation:

Biotic Index= 2 (n Class I) + (n Class II) Where:

n= number of macroinvertebrate taxa.

Values obtained in the present study were 76 for Gr-1, 71 for Gr-2, and 70 for Gr-3. Beck (1955) found that streams receiving only moderate pollution had values for the Biotic Index ranging from 1 to 6. Streams with little or no organic pollution had values greater than 10. This would again indicate that that the grazed sites were not significantly impacted by grazing.

Another method of using macroinvertebrates to assess water quality which alleviates some of the shortcomings of the indicator organism technique is to examine the characteristics of the community rather than the individual taxa. A common method here is to use a diversity index such as the Shannon-Weaver index (Wilhm, 1970). Diversity indices provide a measure of water quality and the effects of pollution on the community structure of macroinvertebrates. In relatively unpolluted systems it is generally observed that there are large numbers of species present with no individual species present in overwhelming abundance. Unpolluted streams usually have Shannon-Weaver diversity ($\bar{d}$) values between 3.0 and 4.0 (Wilhm, 1970) while the equitability (e) ranges from 0.6 to 0.8 (Weber, 1973). Median diversity at Gr-1 was 3.11 (range 2.25 to 3.72), for Gr-2 the median was 2.79 (range 1.83 to 3.30), and for Gr-3 the

Table 5. Macroinvertebrate diversity ($\bar{d}$) for each sampling date.

Date	Gr-1	Gr-2	Gr-3
June 6	2.64	2.79	2.37
July 6	2.76	3.09	2.53
August 8	2.25	2.86	2.62
September 10	3.14	2.62	2.56
October 22	2.82	2.91	1.86
November 24	3.65	2.49	3.41
December 31	3.45	2.36	2.30
January 27	3.52	3.30	2.41
February 24	3.72	1.83	3.70
March 24	2.60	2.43	1.91
April 28	3.11	2.98	1.92
May 29	3.39	3.15	2.07
Median	3.11	2.79	2.37

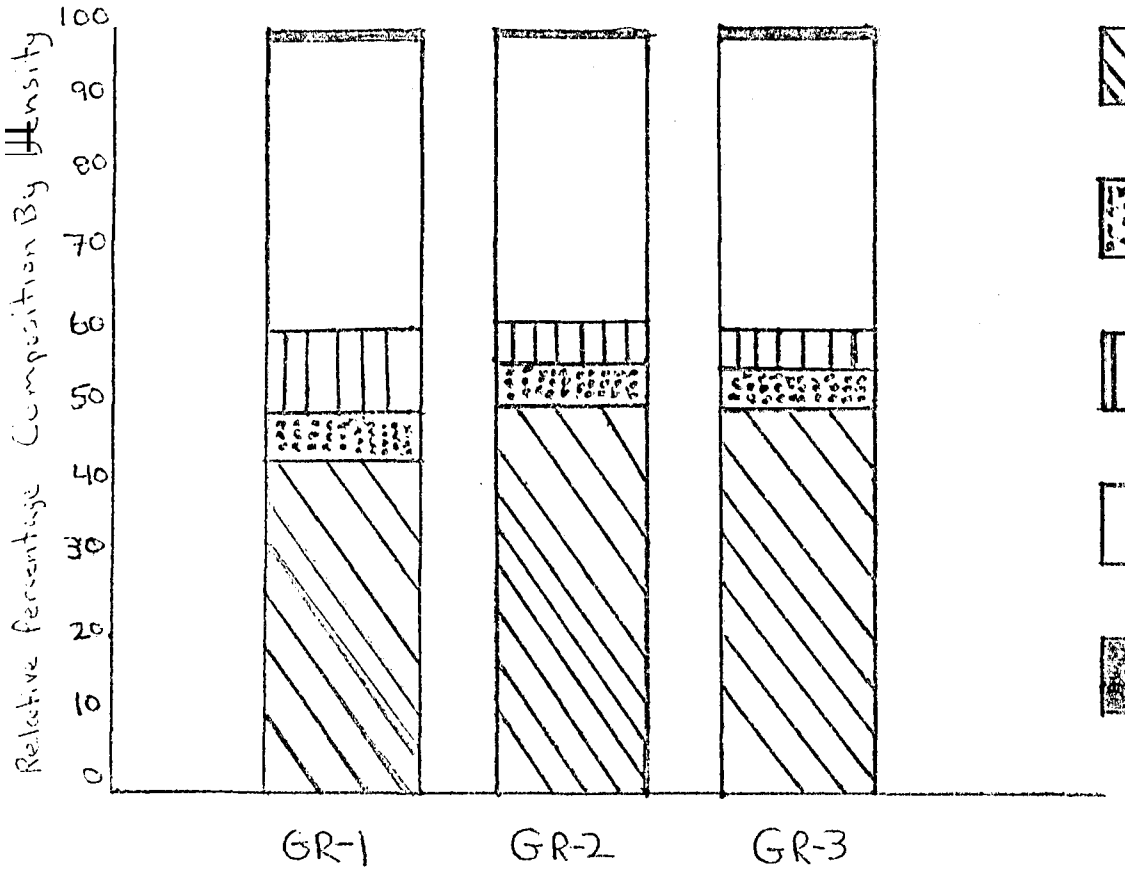
Table 6. Macroinvertebrate equitability (e) for each sampling date.

Date	Gr-1	Gr-2	Gr-3
June 6	0.51	0.39	0.50
July 6	0.33	0.41	0.40
August 8	0.28	0.50	0.57
September 10	0.65	0.40	0.39
October 22	0.39	0.42	0.19
November 24	0.78	0.33	0.52
December 31	0.61	0.28	0.52
January 27	0.55	0.48	0.48
February 24	0.70	0.21	0.79
March 24	0.38	0.37	0.41
April 28	0.38	0.46	0.23
May 29	0.54	0.44	0.24
Median	0.51	0.40	0.41

median was 2.37 (range 1.86 to 3.70) (Table 5). This would indicate that Gr-2 and Gr-3 may be slightly stressed compared to the control site. Equitability values are thought to be more sensitive to slight pollutional stress than diversity (Weber, 1973) and would again indicate that Gr-2 and Gr-3 may be stressed (Table 6). These differences are slight and not amenable to rigorous statistical analysis. Moreover the low values at Gr-3 may be indicative of environmental perturbations (anchor ice) not directly attributable to cattle grazing.

Another method of community analysis is to examine relative percentage composition of the major groups. In an unpolluted situation it would be expected that no single group would be present in overwhelming abundance compared to the other groups. Relative percentage composition by density and biomass is shown in Figure 2 for the macroinvertebrates. All three sites are very similar with respect to density as Ephemeroptera and Diptera dominate in all cases. However they are slightly more dominant at the grazed sites (Gr-2 and Gr-3). The same is true for biomass except that here the Trichoptera are somewhat more important due to their larger-sized individuals compared to the Ephemeroptera. The relative percentage composition values for density and biomass would not indicate that the macroinvertebrate communities are stressed.

The indicator organism concept may also be applied to algae, especially the diatoms (Lowe, 1974). Taxa identified from the periphyton samples are presented in Table 7, showing their occurrence by site and date. No significant differences exist between the control site (Gr-1) and the grazed site (Gr-3). A number of taxa tolerant of pollution such as Oscillatoria, Euglena and Nitzchia (Palmer, 1969) were collected. However



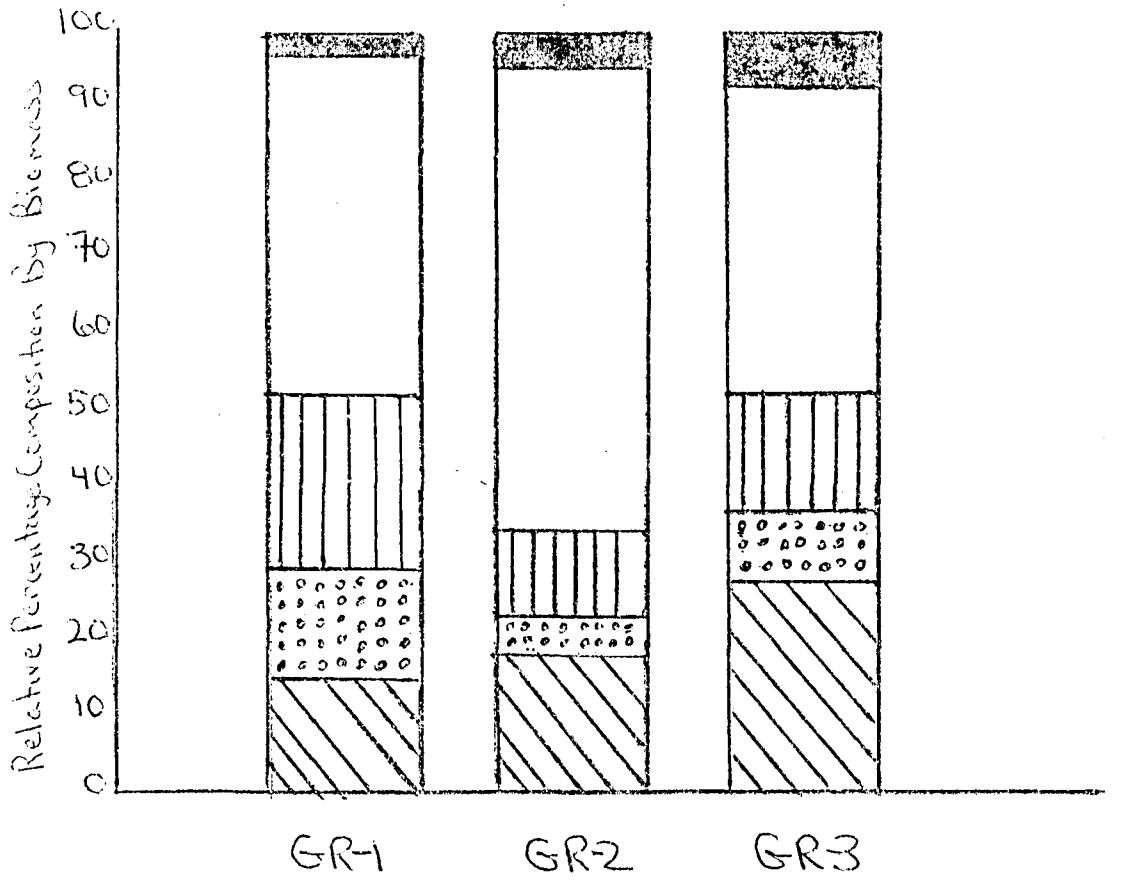


Figure 2. Relative percentage composition of the major macroinvertebrate groups by density (upper) and biomass (lower) for Trout Creek.

Table 7. Algal Species List by Site and Collection Date

	GR-1												GR-3											
month	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Division Bacillariophyta																								
Achnanthes lanceolata	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
A. minutissima	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Amphipleura pellucida						+	+						+											+
Amphora ovalis	+	+		+				+		+		+	+											+
A. perpusilla	+			+				+		+			+											+
Asterionella formosa	+						+		+									+				+		
Caloneis amphisbaena		+												+										+
C. ventricosa				+			+					+			+			+						+
Cocconeis sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
C. pediculus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
C. placentula	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cyclotella meneghiniana	+		+								+					+								
Cymatopleura solea	+	+		+			+	+	+							+					+	+		
Cymbella minuta	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
C. sinuata			+																				+	+
C. turgida	+	+																						
Denticula sp.			+				+						+											
Diatoma anceps													+						+	+			+	+
D. tenue							+	+	+															
D. tenue var. elongatum						+					+						+			+	+	+	+	
D. vulgare	+	+		+		+	+	+	+	+			+				+	+	+	+	+	+		+
Diploneis sp.		+	+																					
Epithemia sorex	+	+	+	+								+												
Eunotia sp.			+																					+
Fragilaria spp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
F. capucina	+	+					+																	
F. vaucheriae					+		+						+							+				
Frustula rhomboides												+												
Gomphonema acuminatum	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
G. olivaceum	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
G. parvulum	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
G. truncatum	+																							
Hannea arcus														+					+					
Melosira granulata			+	+	+			+				+		+	+	+								+
M. varians			+		+							+			+									+

Table 7. (continued)

	GR-1												GR-3											
month	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Division Bacillariophyta																								
Meridion circulare								+												+	+			
Navicula spp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Navicula clementis			+																					
Navicula cryptocephala	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
N. exigua	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
N. exigua var. capitata	+	+	+				+						+			+		+						+
N. pupula	+	+		+		+		+				+	+	+	+	+		+		+		+		+
N. pupula var. capitata		+	+							+														
N. radiosa			+					+																
N. rynchocephala	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
N. viridula	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Neidium spp.		+						+	+			+		+	+	+							+	+
N. binode	+	+	+																					
N. temperi						+	+																	
Nitzschia spp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
N. dissipata																				+				
N. holsatica						+					+						+							
N. linearis		+			+															+	+			+
N. palea	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
N. sigmoidea	+	+	+	+			+		+	+		+	+			+								
Pinnularia spp.	+	+	+											+	+							+	+	
P. mesolepta	+	+																						
Rhoicosphenia curvata								+	+															
Rhopalodia gibba	+		+						+			+		+										
Rhopalodia gibberula												+												
Stauroneis kriegeri										+		+												
Surirella angustata			+									+												
S. ovalis	+					+	+	+	+	+	+	+							+	+				
S. ovata	+																							
Synedra ulna	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Table 7. (continued)

	GR-1												GR-3											
month	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Division Chlorophyta																								
Ankistrodesmus falcatus		+		+																				
Chaetophora elegans					+										+									
Chlamydomonas sp.					+																			
Cladophora sp.			+		+		+	+	+	+	+	+						+			+			
Closteriopsis longissima	+				+		+	+	+	+							+	+				+	+	
Closterium spp.																+								
Crucigenia sp.																	+							
Cosmarium spp.		+			+								+											
Oocystis sp.																	+							
Pediastrum duplex	+	+	+				+	+	+					+		+							+	
P. tetras				+																				
Scenedesmus acuminatus			+	+																				
S. quadricauda	+	+	+	+	+							+				+	+			+				+
Spirogyra sp.			+	+			+	+	+	+	+	+									+	+		
Staurastrum spp.			+					+				+			+							+		+
Ulothrix sp.	+		+															+			+			
Division Chrysophyta																								
Dinobryon sp.									+												+	+		
Hydrurus foetidus																			+	+	+			
Division Cyanophyta																								
Anabaena sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Dactylococcopsis raphidioides	+		+	+	+		+					+		+	+		+	+	+	+	+	+		
Lyngbya sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Merismopedia sp.																					+			
Oscillatoria sp.	+	+	+				+		+								+				+			
Phormidium sp.															+	+	+							
Nostoc sp.	+																							
Division Euglenphyta																								
Euglena spp.	+																					+		
Phacus sp.			+																					
Trachelomonas sp.			+	+											+	+								
Division Rhodophyta																								
Batrachospermum sp.								+	+													+		

Table 8. Percentage by weight of each size class in substrate samples.

Size class	GR-1		GR-2		GR-3	
	AUGUST	MARCH	AUGUST	MARCH	AUGUST	MARCH
25.7 mm +	11.1	32.8	12.5	27.2	0.9	8.3
12.7-25.7 mm	23.7	32.6	24.9	26.8	23.5	7.6
5.2-12.7 mm	24.5	16.1	28.8	25.1	37.7	33.4
2.8-5.2 mm	15.3	6.1	9.7	7.4	9.4	20.3
1.0-2.8 mm	15.3	8.2	10.7	8.1	11.7	16.5
less than 1.0 mm	10.1	4.3	13.4	5.5	16.9	13.9

as mentioned previously for macroinvertebrates, the presence of a tolerant form does not necessarily signify that pollution is present. The periphyton samples therefore do not indicate a significant impact by grazing.

The substrate analysis results are shown in Table 8. The major point of interest is the fine sediment less than 1.0mm in size as this may have profound effects such as smothering, reduction of food sources and elimination of cryptic forms (Cordone and Kelly, 1961). The August samples reflect conditions existing after approximately one month of grazing. The percentage of fine sediments is somewhat larger at Gr-3 than the control site with Gr-2 having an intermediate value. The March samples were taken approximately six months after the cessation of grazing. The fine sediment component is reduced at all sites compared to the August samples. However the value at Gr-3 is still elevated above the control value. This may indicate that grazing did in fact increase sedimentation although natural bank sloughing in the area could be responsible. Increased amounts of fine sediment generally results in reduced productivity of macroinvertebrates since coarse substrates are thought to be the most productive. The finer substrate is more subject to shifting and the scouring effect may greatly reduce plant life. The lower biomass of macroinvertebrates found at Gr-3 has been attributed to other factors but may be due in part to the increase of fine sediment as a result of cattle grazing activities.

SUMMARY AND CONCLUSIONS

After an intensive one year study on Trout Creek, Manitou Experimental Forest, no significant differences could be found in macroinvertebrate density and composition between an ungrazed location and a grazed area. Biomass values were similar at the control site and one grazed site while a second grazed site had a considerably lower biomass. Diversity and equitability of the

macroinvertebrate communities in the grazed areas were reduced compared to the control site. This may indicate a slight degree of stress due to grazing or as a result of other environmental factors (anchor ice). Relative percentage composition by density and biomass was similar at all three sites. Macroinvertebrate taxa generally considered to be intolerant of organic pollution were collected at each site in significant numbers. This would indicate that clean water conditions prevailed at all sites throughout the study. The composition of the algal community also indicated a clean water situation in the grazed area. One potential impact of grazing was an increase in the proportion of fine sediments (less than 1.0 mm) in the substrate at a grazed site.

While the data indicates that no significant degradation of water quality occurred as a result of grazing, it would be improper to apply this finding to other situations. The study area, including the control site, appeared to have been affected by impacts in the past and may not have been truly representative of a completely natural situation. One of the most notable potential impacts of cattle grazing is the reduction of riparian vegetation. All of the sampling sites on Trout Creek had a complete absence of canopy and were thus completely exposed to incident solar radiation. Thus the impact of canopy removal could not be studied. If the stream had been canopied and there were a significant utilization of the riparian vegetation by cattle, it is possible that an increase in stream temperature might have occurred. This could have far reaching effects on the stream biota. Furthermore, reduction of riparian vegetation increases the frequency of bank cave-in as the root system aids in holding the soil together. The area studied on Trout Creek seemed to be very susceptible to cave-in even

in the ungrazed area. Based upon the finding of intolerant macroinvertebrate and algal taxa in the grazed area, it does appear that grazing did not introduce significant amounts of nutrients into the water. Due to such naturally occurring environmental perturbations as anchor ice formation, it is difficult to ascribe any of the observed differences between the control site and the grazed sites to grazing effects. Combining this to the diffuse type grazing where the animals were not confined to an area in immediate contact with the stream, the results obtained indicate little or no impact on stream water quality as assessed by macroinvertebrates due to the effects of low density grazing.

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Table 1. Density of macroinvertebrates (organisms/m^2) at Site Gr-1, June 1977 to May 1978.

Taxon	J	J	A	S	O	N	D	J	F	M	A	M
Ephemeroptera												
Baetis sp.	9	1724	1793	501	1013	18	751	461	531	463	581	614
Paraleptophlebia sp.	4	11	15	26	160	36	49	29	117	11	54	115
Tricorythodes sp.	45	1324	157	41	40	18	23	43	20	2	11	13
Ameletus sparsatus	4	0	0	0	0	0	0	0	0	0	5	0
Ephemerella inermis	0	7	0	0	0	0	0	0	0	0	0	0
Ephemerella micherneri	0	0	9	0	4	4	9	14	13	20	18	20
Rhithrogena sp.	0	254	17	0	0	0	0	0	0	0	4	140
Epeorus longimanus	0	0	0	0	0	2	0	0	0	0	0	0
Cinygmula sp.	0	0	0	0	0	0	0	2	0	0	0	0
Plecoptera												
Alloperla sp.	4	32	204	129	254	32	167	94	160	32	18	0
Skwala parallela	0	54	37	15	22	5	20	29	16	5	4	20
Isoperla sp.	0	0	0	0	0	0	2	0	5	2	13	16
Capnia sp.	0	0	0	0	0	0	27	7	0	0	0	0
Nemoura sp.	0	0	0	0	0	0	0	5	5	0	2	0
Zapada cinctipes	0	0	0	0	0	0	0	0	0	0	0	4
Coleoptera												
Optioservus sp.	0	19	28	15	9	4	4	0	7	7	14	9
Agabus sp.	0	4	0	0	0	0	0	0	0	0	2	0
Trichoptera												
Brachycentrus sp.	0	2	7	19	45	0	0	5	23	25	32	13
Cheumatopsyche sp.	0	60	65	385	504	85	248	106	220	182	198	99
Hydropsyche sp.	0	13	0	0	95	5	14	11	18	0	0	0
Hydroptila sp.	0	19	4	0	2	0	0	11	4	0	5	5
Glossosoma sp.	0	17	9	22	50	4	38	9	59	47	31	13
Limnephilus sp.	0	0	0	0	0	2	0	2	2	0	2	0
Diptera												
Tipula sp.	4	7	0	11	9	4	7	16	27	18	13	2
Hexatoma sp.	0	0	17	13	5	2	2	4	4	0	7	27
Simulium arcticum	2	1221	1520	114	52	5	76	29	14	23	697	94
Atherix pachypus	0	222	84	9	18	4	31	45	65	49	70	56
Pericoma sp.	0	2	0	0	2	0	2	2	0	0	9	0
Palpomyia sp.	0	15	0	0	0	0	0	0	0	0	7	7
Chironomidae pupae	19	26	24	19	4	2	16	7	49	4	5	14
Ablabesmyia sp.	22	56	22	7	5	5	23	56	29	2	16	11
Cricotopus sp.	0	157	13	43	13	5	56	166	115	4	0	40
Diamesa sp.	0	0	0	0	0	0	169	81	29	0	0	0

Table 1. (continued)

Taxon	J	J	A	S	O	N	D	J	F	M	A	M
Eukiefferiella sp.	0	0	0	30	31	20	151	418	178	4	68	77
Micropsectra sp.	0	28	0	0	0	0	0	0	0	0	32	0
Orthocladius sp.	172	118	93	151	61	34	194	490	173	18	144	104
Phaenopsectra sp.	17	0	0	0	0	0	0	0	0	0	0	0
Potthastia sp.	4	15	0	0	0	9	0	0	0	0	0	0
Psectrocladius sp.	0	0	0	11	0	0	0	0	0	0	0	0
Rheotanytarsus sp.	4	0	17	17	11	0	65	151	31	2	81	61
Thienemanniella sp.	0	0	39	26	14	14	198	362	135	7	9	13
Tribelos sp.	0	37	0	0	0	0	0	0	0	0	0	0
Odonata												
Ophiogomphus severus	9	2	4	0	4	0	0	2	0	0	0	2
Hydracarina												
Lebertia sp.	0	2	0	0	0	0	0	0	0	0	0	2
Amphipoda												
Hyallela azteca	0	2	0	0	0	0	2	2	0	0	2	0
Gastropoda												
Physa sp.	4	0	0	0	0	0	0	0	0	0	2	0
Helisoma sp.	2	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta												
Eiseniella tetraedra	4	0	2	0	0	0	0	0	0	4	0	2

Table 2. Density of macroinvertebrates (organisms/m^2) at Site Gr-2, June 1977 to May 1978.

Taxon	J	J	A	S	O	N	D	J	F	M	A	M
Ephemeroptera												
Baetis sp.	93	1232	690	1395	954	864	1643	571	1168	378	1179	1040
Paraleptophlebia sp.	11	24	11	24	90	45	45	38	54	14	77	135
Tricorythodes sp.	17	262	136	47	9	45	18	20	4	2	76	50
Ameletus sparsatus	0	0	0	0	0	0	0	0	0	0	0	2
Ephemerella inermis	32	7	0	0	0	0	0	0	0	0	0	2
Ephemerella micherneri	0	9	0	0	16	5	11	4	5	5	27	13
Rhithrogena sp.	0	460	9	0	0	0	0	4	0	0	0	221
Plecoptera												
Alloperla sp.	19	82	62	245	211	140	85	61	72	104	106	27
Skwala parallela	4	41	15	24	9	9	0	2	0	2	2	36
Isoperla sp.	4	0	0	0	0	0	2	0	2	2	11	7
Capnia sp.	0	0	0	0	0	0	81	34	0	0	0	2
Nemoura sp.	0	0	0	0	0	0	0	2	4	2	0	0
Zapada cinctipes	0	0	0	0	0	0	0	0	0	0	2	7
Taenionema sp.	0	0	0	0	67	0	0	0	0	0	0	0
Coleoptera												
Optioservus sp.	15	26	15	43	36	5	4	4	0	0	11	0
Agabus sp.	0	2	0	0	0	0	0	0	0	0	0	0
Helichus sp.	2	2	0	0	0	0	0	0	0	0	0	0
Trichoptera												
Brachycentrus sp.	2	17	4	45	36	7	5	5	5	14	11	18
Cheumatopsyche sp.	2	7	67	254	263	128	90	27	54	50	36	27
Hydropsyche sp.	0	0	0	0	2	4	4	4	4	0	0	0
Hydroptila sp.	13	11	11	0	2	0	0	2	0	0	0	4
Glossosoma sp.	0	67	2	26	70	32	23	4	22	10	23	31
Agapetus sp.	0	0	0	0	0	2	0	0	0	0	0	0
Limnephilus sp.	0	0	0	0	0	0	0	0	0	0	2	0
Oecetis sp.	0	0	0	0	0	0	0	0	4	0	0	0
Diptera												
Tipula sp.	4	26	45	11	58	20	18	14	18	29	13	9
Hexatoma sp.	0	7	30	39	16	2	2	5	7	45	88	68
Simulium arcticum	1039	587	108	181	85	101	135	36	36	27	707	284
Atherix pachypus	4	22	7	39	14	5	9	13	23	4	14	16
Palpomyia sp.	9	2	0	0	0	0	0	0	0	0	59	25
Chironomidae pupae	71	19	11	11	4	0	0	7	4	0	0	5
Ablabesmyia sp.	30	39	30	4	13	5	2	29	5	2	47	38
Cricotopus sp.	82	170	11	73	2	7	4	108	16	0	0	68

Table 2. (continued)

Taxon	J	J	A	S	O	N	D	J	F	M	A	M
Diamesa sp.	0	0	0	0	0	0	49	122	0	0	0	0
Eukiefferiella sp.	174	0	0	45	13	16	144	324	0	2	108	61
Micropsectra sp.	0	0	0	0	0	0	0	0	0	0	56	0
Orthocladius sp.	531	88	161	187	67	34	106	470	47	5	146	108
Potthastia sp.	142	15	0	0	0	7	0	0	0	0	0	0
Psectrocladius sp.	0	0	0	8	0	0	0	0	0	0	0	0
Rheotanytarsus sp.	26	22	0	9	13	14	76	164	11	0	103	59
Thienemanniella sp.	99	56	0	0	18	16	74	263	23	2	67	9
Tribelos sp.	0	37	0	0	0	0	0	0	0	0	0	0
Odonata												
Ophiogomphus severus	4	7	7	0	0	0	4	2	0	2	0	11
Hydracarina												
Lebertia sp.	0	0	0	4	0	0	0	0	0	0	0	0
Sperchon sp.	0	0	0	0	2	2	0	0	0	0	0	0
Gastropoda												
Physa sp.	0	0	0	0	0	0	2	2	0	0	0	0
Oligochaeta												
Eiseniella tetraedra	0	0	0	0	0	0	0	0	2	0	0	0

Table 3. Density of macroinvertebrates (organisms/m^2) at Site Gr-3, June 1977 to May 1978.

Taxon	J	J	A	S	O	N	D	J	F	M	A	M
Ephemeroptera												
Baetis sp.	17	1636	1137	606	1528	439	142	218	549	153	374	842
Paraleptophlebia sp.	0	0	0	7	11	81	0	0	72	2	14	4
Tricorythodes sp.	0	1537	329	75	22	9	0	0	18	0	4	13
Ameletus sparsatus	0	0	0	0	4	0	0	0	0	0	2	4
Ephemerella inermis	9	0	0	0	0	0	0	0	0	0	0	0
Ephemerella michemeri	0	15	11	0	4	9	0	0	0	0	0	2
Rhithrogena sp.	0	303	45	0	0	2	0	0	0	0	0	20
Plecoptera												
Alloperla sp.	17	41	159	112	104	122	65	29	106	9	27	4
Skwala parallela	0	7	17	9	5	9	0	0	13	0	0	23
Isoperla sp.	0	0	0	0	0	4	0	0	2	5	2	7
Capnia sp.	0	0	0	0	0	0	4	9	0	0	0	0
Nemoura sp.	0	0	0	0	0	0	0	2	2	0	2	0
Zapada cinctipes	0	9	0	0	0	0	0	0	0	0	0	4
Taenionema sp.	0	0	0	0	11	5	0	0	0	0	0	0
Pteronarcella badia	0	0	0	0	0	0	0	0	0	2	0	0
Coleoptera												
Optioservus sp.	2	39	34	17	11	5	0	0	0	2	4	0
Agabus sp.	0	2	0	0	0	0	0	0	0	0	0	0
Helichus sp.	0	0	0	4	0	0	0	0	0	0	0	0
Haliplus sp.	0	0	0	0	2	0	0	0	0	0	0	0
Trichoptera												
Brachycentrus sp.	0	0	0	4	7	4	2	2	4	0	0	7
Cheumatopsyche sp.	0	2	22	24	101	326	36	7	160	22	13	0
Hydropsyche sp.	0	0	0	0	0	31	0	0	14	0	0	0
Glossosoma sp.	2	4	0	7	45	32	196	47	25	18	2	4
Diptera												
Eriopterini	0	0	0	43	0	0	0	0	0	0	0	0
Tipula sp.	4	4	9	0	38	5	5	0	23	9	5	2
Hexatoma sp.	0	2	7	19	11	4	2	0	9	0	7	20
Simulium arcticum	136	2329	841	299	115	108	18	16	11	11	1120	599
Atherix pachypus	4	37	24	0	4	49	5	2	52	0	11	0
Pericoma sp.	0	0	0	0	0	0	0	0	2	0	0	0
Palpomyia sp.	0	11	0	0	0	0	0	0	0	0	11	5
Empididae	0	0	0	0	4	0	0	0	0	0	0	0
Chironomidae pupae	7	19	0	4	0	2	0	0	18	0	13	7

Table 3. (continued)

Taxon	J	J	A	S	O	N	D	J	F	M	A	M
Ablabesmyia sp.	2	26	0	2	4	0	0	2	27	0	9	9
Cricotopus sp.	13	202	4	19	7	13	0	0	70	0	22	0
Diamesa sp.	0	0	0	0	0	0	0	2	0	0	0	0
Eukiefferiella sp.	0	84	0	2	16	50	7	27	61	0	31	14
Micropsectra sp.	4	0	0	0	0	0	0	0	0	0	0	99
Orthocladius sp.	13	187	4	50	34	54	2	16	97	2	68	34
Potthastia sp.	0	0	0	0	0	11	0	0	0	0	0	0
Psectrocladius sp.	0	0	0	11	0	0	0	0	0	0	0	0
Rheotanytarsus sp.	0	28	0	0	13	38	0	2	0	0	34	16
Thienemanniella sp.	0	77	0	0	13	20	0	29	92	0	11	0
Tribelos sp.	2	0	0	0	0	0	0	0	0	0	0	0
Odonata												
Ophiogomphus severus	0	2	2	4	0	4	2	0	0	0	0	2
Hydracarina												
Lebertia sp.	0	0	0	2	0	0	0	0	0	0	0	0
Sperchon sp.	0	0	0	0	0	2	0	0	0	0	0	0
Amphipoda												
Hyallela azteca	0	0	0	0	0	0	0	0	5	0	0	0
Oligochaeta												
Eiseniella tetraedra	0	0	0	0	5	5	0	0	4	0	0	0
Limnodrilus sp.	0	54	0	0	0	0	0	0	0	0	0	0